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Capture Fishery Biology of Skipjack in Western and Southern Waters of North Maluku Province

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Abstract

Study of capture fishery biology of skipjack (*Katsuwonus pelamis*) was carried out in western (Zone A) and southern (Zone B) waters of North Maluku Province in April 2012 to March 2013. The study has collected and observed 1200 skipjack samples. Skipjack length – weight equation for Zone A was: W = 0.016 $L^{3,035}$ and for Z*one B was*: $W = 0{,}014\, L^{3{,}079}$, where both had isometric growth. Length frequency analysis of skipjack using Tanaka method for fish catched in Zone A and B resulted in 3 age groups having similar size modes or mean lengths for both zones, namely 32.9 cm, 43.9 cm and 51.9 cm. Maximum FL length (L_∞) of skipjacks catched in zone A reached 75cm at age of 56 months and in zone B reached 76cm at age of 56 months. Range of FL of skipjacks catched in zone A was 26.0 – 72.0 cm while for zone B was 26.0 – 71.0 cm. Levels of gonad maturity of skipjacks catched in zone A and zone B were found to be in two groups, they were TKG IV (ripe) and TKG V (spent). Value of L_m of skipjacks in zone A and zone B or North Maluku waters was found to be 43 cm.

Keywords: biology, skipjack fishery, North Maluku Province, western waters, southern waters.

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1. Introduction

Skipjack (*Katsuwonus pelamis*) resources are renewable resources. Renewable means when a skipjack resource are partially exploited or captured, remain population have ability to recovery through reproduction.

Having that renewable properties means that skipjack populations must not be used carelessly without understanding fish age structures and sex ratios of available skipjack populations. When a skipjack population fish age structures is not supporting good recovery rate or has a slow recovery ability then it could be said that the skipjack resource is threatened (to extinction).

.Skipjack (*Katsuwonus pelamis*) is one of most important fishery resources both as export commodity and as local domestic consumption. It has a significant role in national income. In well developed countries such as Japan, South Korea and United States of America (USA), research programs on skipjack has been advanced which covers its biological aspects, distributions, and its technical fishing technology. Unfortunately, skipjack research programs in Indonesia are still limited which in turn make very limited available information about skipjack in Indonesia area [1] So far, most research's carried out on skipjack in Indonesia are on its fishing.

Skipjack fishing activities in western and southern waters of North Maluku Province have not yet been well regulated and not following good sustainable fishery code of conducts. Fishers tend to fish freely wherever and whenever they wish, including to fish undersized skipjack populations. For its better fishing management, skipjack biological information is an urgent needs for North Maluku. Study of some biological characteristics of skipjack in western and southern waters of North Maluku will be useful to develop better management of skipjack fishery.

2. Research Methods

2.1 Location and time of study

The study was carried out in western and southern waters of North Maluku Province focusing on two fishing ports mainly used as fishing base of skipjack fishery (pole and line) in North Maluku. Those two fishing ports are Dufa-dufa Fishing Port in Ternate City and Panamboang Fishing Fort in Bacan of South Halmahera District. Field data collection was carried out for a year, from April 2012 to March 2013. Based on its ecosystem characteristics and depths, western and southern waters of North Maluku Province are divided into two zones as presented in Table 1 and its map can be seen in Figure 1; Biological data collected included fish weight and length of fish samples taken from skipjack catched by pole and line fishers. Samples were taken once a week from fishers at each port stations at Dufa-dufa and Panamboang Bacan. Sample fishes were taken randomly from pole and line fishers with total samples numbers were 25 fishes per week, and made a total of 100 sample fishes for each port station. Sample can be used to explain a real population [2,3]. Measurement of skipjack FL used measuring

board with 0.1 cm accuracy level while fish weights were measured using weighing tools with 0.1 Kg accuracy.

Table 1. General description of 2 zones in Western and Southern waters of North Maluku Province.

Description	Zone	
	A	**B**
Area and depth	1657.7km², depth up to ±3000m	1347.4km², depth up to ±3000m
Coastal settings	Directly connected to open seas.	Islands groups and bays
Administratives area	Ternate City	South Halmahera District
Geographic focus for research analysis	0.435349^0 – 0.97977^0North and 126.800316^0 – 127.042069^0 East	0.855687^0 - 1.096369^0 South and 127.09412^0 - 127.543124^0 East

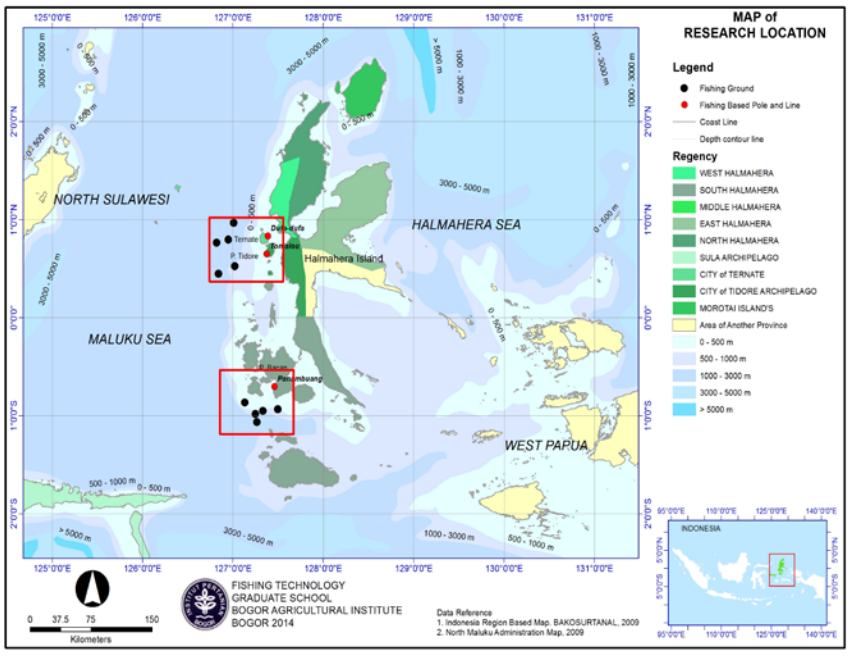


Fig1. Location and zoning research in the territorial waters of the South West and North Maluku

2.2 Fish Length – Weight Relationship

Relationships of length (FL) and weight (W) of skipjacks was seprately analyized for samples taken in zone A and zone B. Calculation of lengh-weight correlation was based on formula given by Effendie [4,5,6].

$$W = aL^b \quad (1)$$

Where:

W = bodi weight (gram)

L = total length (cm)

$a$and b = constants

Statistical test for b = 3 used **t-test** at α =5% [7] using equation:

$$t_{hitung} = \frac{3-b}{s/\sqrt{n}} \quad (2)$$

2.3 Fish Length – Weight Relationship

Estimates of skipjack growth were calculated based on fish length frequencies and age groups by using Tanaka method. Cohort grouping based on length frequencies would produce mean fish length for each age groups. Values of mean fish lengths are then plotted against age to produce fish growth curves. Estimates of growth coefficient (K) and infinity length (L_∞) were calculated with Ford-Walford method [7] by using regression between fish lengths at ages t (Lt) and fish length at ages t+1 (Lt+1) which would resulted in growth parameter equations K= - Ln.b and L_∞= a/(1-b). Then, empirical formula was used to calculate value of t_0 (theoretical fish ages) [8]:

$$Log(-to) = -0.3922 - 0.2752logL = -1{,}038logK \quad (3)$$

Once values of K, $L_\infty$and t_0 have been known, population growth model and length-weight relationships could be obtained for skipjack populations of North Maluku Province by using growth model of Von Bartalanffy written as follows:

$$Lt = L_\infty\left(1 - e^{-K(t-t_0)}\right) \quad (4)$$

Where:

Lt = fish length at age t K = growth coeficient

$L\infty$ = infinity length t_0 = fish age when its length is zero.

t = time

2.4 Size composition

Skipjack samples form each zones in western and southern waters of North Maluku Province were first analyzed with single sample t-test to find samples represesntiveness, then length classes were developed to define the size of frequencies. Finally, size composition graphics could be developed using *Microsoft Excel* 2007.

2.5 Gonad maturity level

Gonad maturity levels were determined visually using desk microscopes by observing gonad characteristics based on classification which using some main gonad criteria as presented in Table 2 below [9].

Table 2 Gonad/ovary maturity classification for skipjack.

TKG	The state ofgonads (ovary)	Description
I	Immature	Ovary is slender, small and almost transparent.
II	Maturing	Ovary is bigger, in pink to cream in color, egg are not yet visible.
III	Mature	Ovary is yellowish in color, eggs are visible.
IV	Ripe	Eggs are big and have clear yellow color, can be squeezed out easily.
V	Spent	Ovary is narrowing, has red color, and has many blood veins.

2.6 Capturable Size

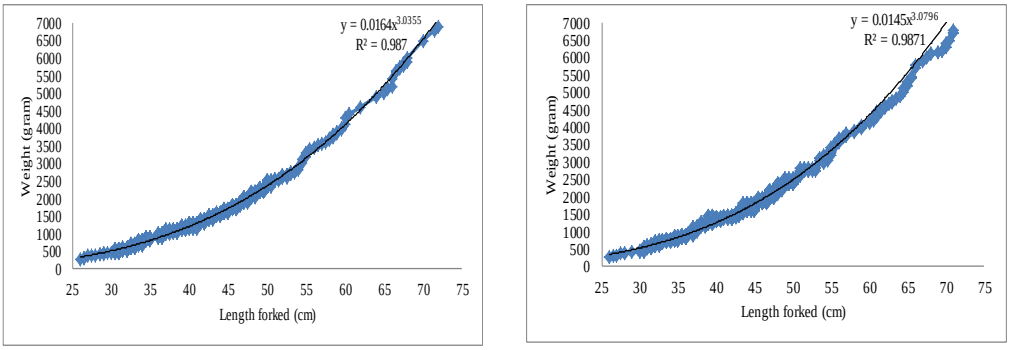
Fish capturable size is fish having total length higher than its length at first maturity (Lm). Value of Lm is calculated from a sigmoid curve between class-mean and proportion (%) of mature skipjack sample. Intercept between F_{50} and sigmoid curve is the value of Lm [10].

3. Results and Discussions

3.1 Results

- **Skipjack length – weight relationships**

Skipjack length – weight relationships in western waters (zone A) and southern waters (zone B) in North Maluku Province are presented in Figure 2. Analysis of sample length-weight with n=1200 for every zone resulted in values of coefficient a= 0.016 and coefficient b=3.035 for zone A while for zone B it had a= 0.014 and b= 3.079. Values of determinant coefficient (R^2) of sample length-weight correlation for zone A and zone B were found to have same value of 0.987 that indicated regression equations produces has a level of accuracy of 98.7%.



Zone A Zone B

Fig 2.Length relationship forked (cm) and weight(grams) of skip jackin zone A and zoneB inthe territorial waters ofNorth Maluku.

By using values of coefficients a and b in regression equation $W = aL^b$ would produce skipjack length-weight equation below:

Zona A : W = 0,016 $L^{3,035}$

Zona B : W = 0,014 $L^{3,079}$

Results of analysis of value b of zone B indicated that value of $t_{hit} < t_{tab}0,05$ or value of b = 3. This explained that skipjack in western waters (zone A) and southern waters (zone B) has an isometric body-forms or its length growths are proportional to weight growth. Even though skipjack of zone A and B has an isometric body, coefficient b of both zones were different. Value of significance for both zones did not intercepted (see Table 3 and Figure 3).

Table 3 Range of significance of coefficient b for zone A and B in North Maluku Province.

Remarks	**Values**	
	Zone A	**Zone B**
Mean (b)	3,035(fat body)	3,079(fat body)
Standard deviation (sd)	0,001	0,001
Significance range (b±sd)	3.0340-3.0360	3.0780-3.0800

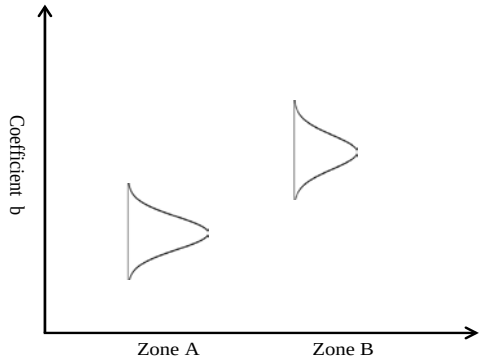


Fig 3. Comparison of values of b of samples for zone A and B

- **Skipjack growth parameters**

Length frequencies analysis using Tanaka method for samples from zone A and B resulted in 3 age-groups (Table 4) where the lower groups were younger than higher groups along with their body length size. Growth analysis based on Tanaka method followed by Ford Walford method resulted in von Bertalanffy growth equation for skipjack population in zone A and B (Table 5).

Table 4 The age group ofskipjackin thewesternwaters(zone A) and Southern (zone B) of the province of North Maluku

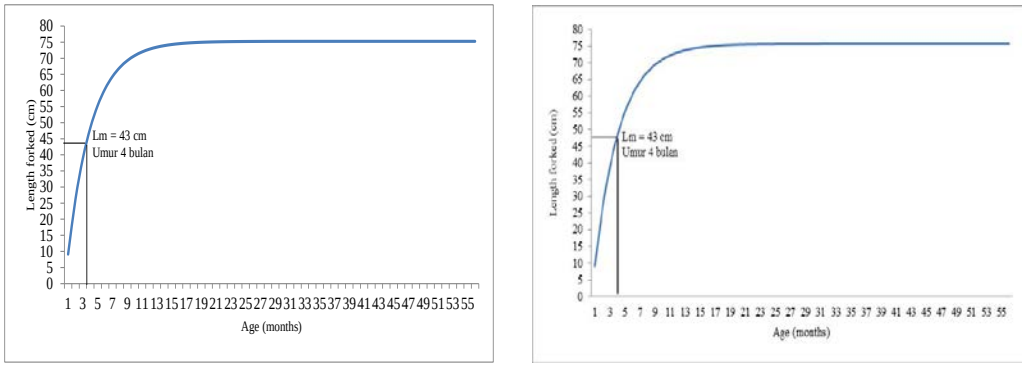
Remarks	Age (t)	L(t)	L(t + dt)
Zone A	1	32.9	43.9
	2	43.9	51.9
	3	51.9	
Zone B	1	32.9	43.9
	2	43.9	51.9
	3	51.9	

Table 5 Estimate values of growth parameter of skipjack in zone A and B.

Growth Parameters			
Remarks	**L∞ (cm)**	**K (months)**	**t_0**
Zone A	75	0,30	0,43
Zone B	76	0,29	0,43

After using growth parameter values in von Bertalanffy equations for skipjack sampled in zone A and B it was resulted in equation $L_t = 75\{1 - e^{0,30(t + 0,43)}\}$ for zone A and equation $L_t = 76\{1 - e^{0,29(t + 0,43)}\}$ for zone B, both produce curve shapes shown in Figure 4. Those equations indicated that skipjacks

samples from zone A could reach maximum FL ((L_∞) of 75 cm at age of 56 months while skipjack sample from zone B could reach maximum FL ((L_∞) of 76 cm at age of 56 months.



Zone A Zone B

Fig 4. Curve resulted from von Bertalanffy growth equation for skipjack from zone A and B in North Maluku Province.

- **Skipjack length size composition**

Skipjack size structure for both samples for Zone A and B can be seen in Figure 5 and 6. Figure 5 shows that ranges of fish body length (FL) for zona A is 26,0 – 72,0 cm, where minimum length was found in January (26,0 cm) and maximum length was observed in March (72,0 cm). Skipjack sampled during March had length size over 43 cm with dominant sizes ranged of 51,0 – 55,0 cm and it is assumed that the fish had undertaken a reproduction cycle. Range of body length (FL) of skipjack sampled in zone B was 26 – 71 cm, where the minimum size was observed in January (26 cm) and maximum size was found in July (71 cm) as shown in Figure 6. Sample fish caught in June were dominated by fish with Lm size, while fish caught in July dominated by fish with size higher than Lm and assumed to undergo a spawning cycle.

- **Skipjack egg maturity level**

Results of gonad maturity level (TKG) over 1200 skipjack samples from zone A and 12000 fish from zone B in North Maluku Province showed they have some different levels of maturity, they were TKG I (*inmature*), TKG II (*maturing*), TKG III (*mature*), TKG IV (*ripe*), and TKG V (*spent*). Percentage of skipjack egg maturity for zone A and zone B based on observing moon period is shown in Table 6. Data in Table 6 shows clearly that skipjack caught in both zone A and B were dominated by immature fish, they were 59,25% for fish from zone A dan 58,42% for zone B. Fish with mature eggs were found as much as 40,75% for zone A and 41,58% for zone B.

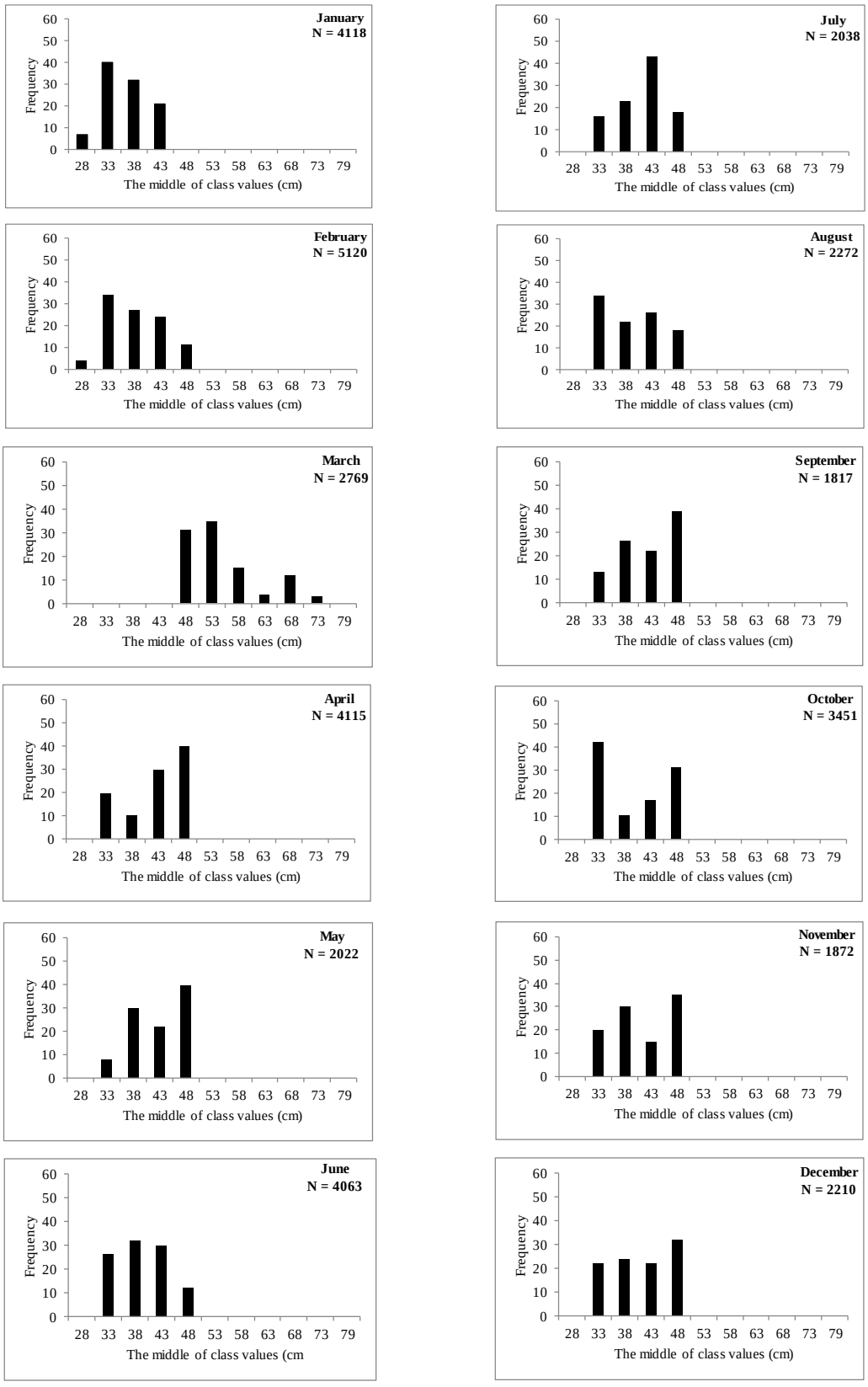


Fig 5. Skipjack size composition caught in western waters (zone A) of North Maluku Province.

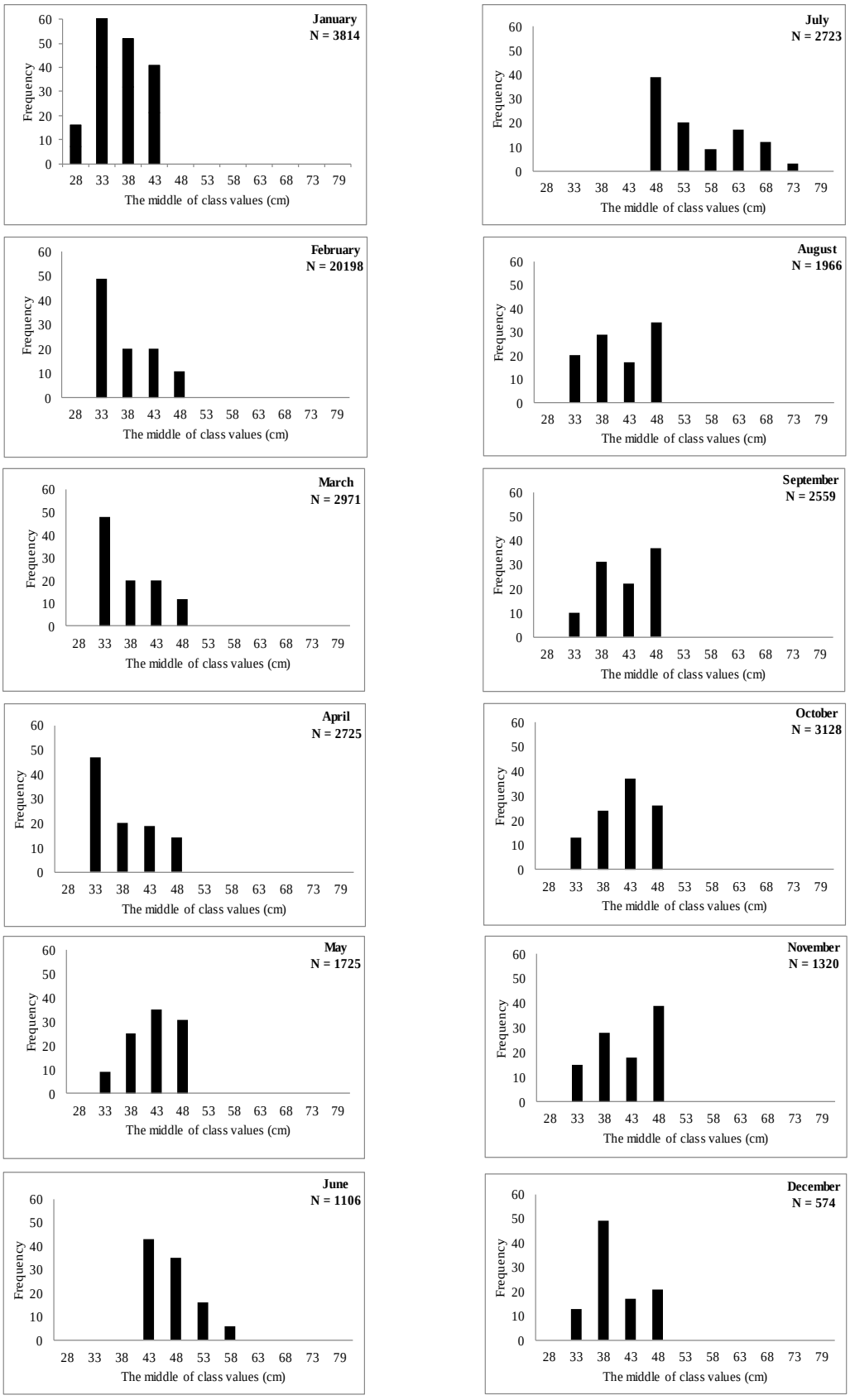


Fig 6. Skipjack size composition caught in southern waters (zone B) of North Maluku Province

Table 6. Percentage of skipjack egg maturity level: (a) Western water (zone A) and (b) southern waters (zone B).

(a)

Observation of period(months)	immaturegonads		Mature gonads		Number of Sample
	Number of individual	Percent (%)	Number of individual	Percent (%)	
January	71	71	29	29	100
February	67	67	33	33	100
March	7	7	93	93	100
April	45	45	55	55	100
May	44	44	56	56	100
June	61	61	39	39	100
July	58	58	42	42	100
August	66	66	34	34	100
September	50	50	50	50	100
October	70	70	30	30	100
November	87	87	13	13	100
December	85	85	15	15	100
Total	711	59,25	489	40,75	1200

(b)

Observation of period(months)	Immaturegonads		Mature gonads		Number of Sample
	Number of individu	Percent (%)	Number of individu	Percent (%)	
January	87	87	13	13	100
February	85	85	15	15	100
March	85	85	15	15	100
April	83	83	17	17	100
May	42	42	58	58	100
June	17	17	83	83	100
July	6	6	94	94	100
August	42	42	58	58	100
September	35	35	65	65	100
October	56	56	44	44	100
November	80	80	20	20	100
December	83	83	17	17	100
Total	701	58,42	499	41,58	1200

- **Skipjack size at its first egg maturity and capturable size**

Based on sigmoid curve, it is found that skipjack samples from both zone A and B had Lm of 43 cm when they were at their first maturity (Figure 7). Sustainable capture fishery should be supported by regulation on capturable size. One criteria used to determine capturable size would be body length over (higher than) its length at first maturity (Lm).

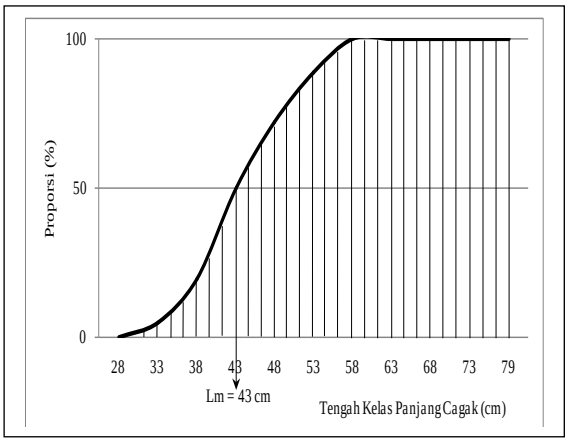


Fig 7. Values of Lm (*length at first maturity*) for skipjack caught in zone A and zone B.

Based on Lm values it can be decided that skipjack capturable sizes for both zone A and B are > 43 – 73cm. Most of capturable skipjack groups in zone A and B were found in months of February to December. Peak season for capturable size skipjack fishing in zone A would be March while in zone B it would be July (Figure 8).

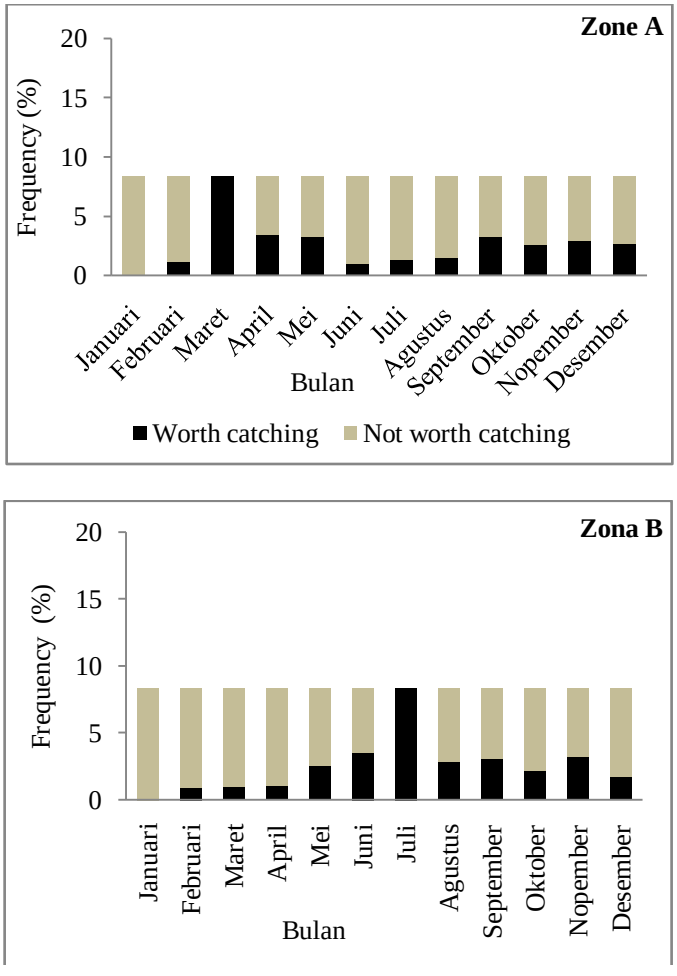


Fig 8.Skipjack capturable sizes for zone A and B.

Capturable skipjacks for zone A and B in North Maluku Province has similar proportion that was 31%. This condition indicated that 69% of skipjack caught in both zone were undersize fish (below capturable sizes) (Table 7).

Table 7 Sample proportions of capturable and non-capturable skipjacks caught in zone A and B in North Maluku Province waters.

Zones	Proportion (%)	
	Capturable	Non-capturabel (undersize)
Western waters (zone A)	31	69
Southern waters (zone B)	31	69

3.2 Discussions

Value of coefficient b calculated from lengh-weight equations was 3.025 for western waters (zone A) and 3.079 for southern waters (zone B) in North Maluku Province, where both zones have similar value of determinant coefficient of 0.987. Statistical t-test resulted values of coefficient b = 3 which meaned that skipjack populations had isometric growth model; in other words increases of length were equal to weight increase. Similar results were also reported for skipjack caught in Banda Sea which had isometric growth [11]; in western waters of Central Sulawesi [12], and in Bone Bay [13]. Those conditions are conform statement made by Uktolseja *at al.* (1981) that skipjacks growth in Sulawesi are isometric. Different results were reported by [1] for skipjack caught in Seram and Nusa Laut areas that had value of b>3 or allometric growth where length increase does not have same rate with weight increase. Different results of growth models found in different waters or areas might be caused by different sample sizes, range of fish sized analyzed or variations in local growth rates [11]. [13] also stated that different results in skipjack growth model could be caused by both fish sized differences and environmental biological and ecological factors. Others comment also made by [14] who stated that difference of values of coefficient b is related to difference of fishing seasons, difference in fish maturity levels, and fishing activity since intensive fishing activity would affect fish population behaviours and growth rates. [1] also stated that when environmental conditions changed frequently or when fish conditions changed then it could lead to change of fish length-weight relationship to shift from cubical form ($b \neq 3$).

Analysis results of skipjack length-weight relationships with Tanaka method for samples caught in western and southern waters (zone A and B) of North Maluku Province gave 3 age groups of fish with similar size modes or mean length sizes of 32.9cm, 43.9cm and 51.9cm. This consistent with reults

reported by [15] that also found 3 skipjacks age groups for samples caught in Sorong (Papua) areas having size modes of 37cm, 54cm, and 64cm. In other repors of [13], it was reported 4 skipjacks age groups caught in Bone Bay having mean length sizes of 38.4cm, 45.5cm, 49.3cm, and 54.9cm; same with skipjack sampled in Pelabuhan Ratu that had 4 age groups with mean length sizes of 33cm, 50cm, 57cm, and 66cm.

Fish maximum length (L_∞) for skipjacks caught in zone A reached 75cm at age 56 months and 76cm at age of 56 months at zone B. Report from [13] showed asimptot length of 76cm for fish caught at Bone Bay, while [16] reported asimptot lengths of 80cm and 73.2cm for skipjacks caught in Sorong area in Eastern Indonesia. Maximum skipjack lengths found in this research are different from maximum lengths of skipjacks sampled in West Sumatera which had L_∞= 87.8cm at age 120 months [17]. Those difference of growth parameters (L_∞ and K) of a fish species at different areas could be affected by environmental factors, such as food availability, water temperatures, and dissolved oxygen [17]; while [18] stated a deviation of fish growth parameters could be related to unsatisfied sampling procedures and different methods used in data analysis.

Skipjack compositions of skipjack caught by pole and line fishing in both zone A and B had a similar pattern, they tended to increase in January to March in zone A and July in zone B. Increase of fish size had been observed from February eventhough dominant fish caught were smaller than Lm. During March in zone A and in June – July in zone B, skipjack sizes had been dominated by fish having lengths more than Lm and had passed first reproduction cycle. Skipjacks undergo spawning along year times in equator waters, in January-April and November-December in Coral Sea Australia [19] and in April-July in Japan [20]. Those information indicates that skipjack sizes compositions always consist of smaller fishes and bigger fishes since reproduction cycles have been experience in previous months.

Observation of maturity levels (TKG) for fishes sampled in both zones in North Maluku Province waters resulted in 5 level of TKG, they were: TKG I (*inmature*), TKG II (*maturing*), TKG III (*mature*), TKG IV (*ripe*), and TKG V (*spent*). These showed that skipjakcs undertake spawning along the year. Research of [11] in Banda Sea found 4 TKG levels, they were TKG I (*inmature*), TKG II (*maturing*), TKG III (*mature*), dan TKG IV (*ripe*).

Capturable fish sized is defined as fish having length more than its length at first maturity Lm. Value of L_m for skipjacks sampled in zone A and zone Be of North Maluku waters is 43cm. Values of L_m are different for skipjakcs populations from different areas, which in general is above 40cm (Table 8).

Capturable and non-capturable skipjack for both zone A and B in North Maluku Province had a similar compositions (Table 7). The high percentage of non-capturable fish caught in North Maluku indicated that most fishers in the province had not yet understood best fishing months (fishing seasons) and safe fishing time which do not harm the skipjack fishing sustainability. Fish caught before maturity could have negative effects on fish recruitment in the area. One way to minimize undersized fishing is to

develop a better fishing policy, for example to use bigger hook sizes used in pole and lines and/or well regulated closed seasons in January-June for Zone A and in January-April for Zone B.

Table 8 Examples of values of L_m for various skipjack populations

Value of L_m (cm) FL	**Sex**	**Country**	**Area/Location**
43,5 – 45,4*)	-	USA	Nort Carolina
40,0 – 45,0*)	Female	USA	Hawai
40,0*)	Female	Cuba	Northeast region
43,0*)	-	Polinesia	Marquesas and Tuamotu Islands
43,0*)	-	Filipina	Bohol Sea
45,0*)	-	Papua New Guinea	Papua New Guinea
41,0 – 43,0**)	-	Madagaskar	Barat Daya Madagaskar

*) [19]

**) [20]

4. Conclusion

Length-weight equation for skipjacks sampled in $Zona\ A : W = 0{,}016\ L^{3{,}035}$ and in z $ona\ B : W = 0{,}014\ L^{3{,}079}$, which both samples followed an isometric growth models. Based on fish length frequency analysis using Tanaka method for both skipjack samples from zone A and B showed 3 age groups having mean lengths of 32.9cm, 43.9cm, and 51.9cm respectively. Maximum FL (L_∞) for skipjacks sampled in zone A reached 75cm at age 56 months while for zone B it was 76cm at same age of 56 months. Ranges of skipjack body length (FL) sampled in zone A was 26.0 – 72.0cm, and in zone B it was 26 – 71cm. Level of fish maturity of skipjacks sampled in zone A and B, consist of 5 categories, they were TKG I (*inmature*), TKG II (*maturing*), TKG III (*mature*), TKG IV (*ripe*), dan TKG V (*spent*). Value of L_m of skipjack samples from both zone A and B was 43cm.

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